CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-174

The San Cayetano Fault and Related "Flexural-Slip" Faults Near Ojai and Santa Paula, Ventura County, California

by

James E. Kahle

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INTRODUCTION

This fault evaluation report (FER) deals with the San Cayetano thrust fault and other related faults which were previously thought to displace late Pleistocene units only. New data that suggest Holocene activity on some of these faults necessitated reevaluation. A statewide program requires the State Geologist to zone faults determined to be sufficiently active (evidence of Holocene displacement) and well-defined (Hart, 1985, p. 5). Said program is called the Alquist-Priolo Special Studies Zones Act and is described by Hart (1985).

The San Cayetano fault and selected "flexural-slip" faults are reported to displace sedimentary units of Holocene age. These faults are located in unincorporated areas of Ventura County, California. One group of faults, called the Oak View faults (Figure 1), is located south of Ojai near Oak View. These are shown on Plate 1, the Matilija 7.5 minute quadrangle. Another group, called the Orcutt/Timber Canyon faults (Figure 1), is located northeast of Santa Paula. These are shown on Plate 3 and Plate 4, the Santa Paula Peak and Fillmore 7.5 minute quadrangles, respectively. The San Cayetano fault is also shown on Plates 3 and 4 as well as Plate 2 (the Ojai 7.5 minute quadrangle).

This reevaluation consists of a review of previous FER's (completed in 1977) and new studies completed since that time. Time limitations precluded detailed field studies but selected locations were investigated to evaluate the faults relative to the newer data. Air photos of the area were reviewed to determine the plotting accuracy of mapped traces and the location of related geomorphic features. Photo sets used were flown by the U.S. Department of Agriculture (1953) and the U.S. Geological Survey (1967, 1969).

SUMMARY OF AVAILABLE DATA

Between the period of the earlier evaluations (Smith, 1977a, b, c, d) and the time of this study new evidence of the ages of uplifted alluvial terrace and fan deposits, based on soil development profiles which were

NOTE: This report includes 11 figures and 4 plates.

tied to limited radiocarbon dates, has been applied to the problem of dating tectonic deformation along the northern margin of the Ventura Basin (Keller and others, 1981a; Rockwell, 1983). Other reports which have dealt with this problem include guidebook articles by Keller and others (1981b; 1982) and more general reports by Yeats and others (1981) and Rockwell and others (1984). Previous fault evaluation reports concluded that evidence for Holocene activity was questionable or lacking, although evidence for late Pleistocene activity was convincing. The ages of various offset alluvial fan or terrace deposits could only be estimated. At that time the criteria of sufficiently active was debatable, although many of the faults were considered well-defined. Careful analyses of soil development on many older fan and terrace surfaces along the Ventura River and in the Orcutt Canyon and Timber Canyon areas have resulted in some tentative correlations of seven depositional surfaces. These range in estimated age from late Historic floodplain deposits (10-20 years old) to as old as 200,000 years. Many of these deposits are offset by faults. The most significant surfaces, for determining "sufficiently active" are those designated Q_1 through Q_4 surfaces (Rockwell, 1983). The Q_3 and Q_4 surfaces are the most significant since no Q_1 or Q_2 surfaces have been proven to be offset. Figure 2 (Rockwell, 1983, Table II) summarizes the soil data and the estimated ages of the various units.

Four groups of faults were evaluated previously and the present reevaluation will be arranged to correspond with this grouping. The San Cayetano fault was evaluated in FER-19 (Smith, 1977c). The Oak View faults were evaluated in FER-29 (Smith, 1977b) along with the Lion Canyon fault (Lion fault on Figure 1), and the Big Canyon and Sisar faults. The Arroyo Parida - Santa Ana faults were evaluated in FER-26 (Smith, 1977d). The Orcutt/Timber Canyon faults were evaluated in FER-18 (Smith, 1977a). Each group is treated separately. The literature used for the previous fault evaluation reports was selectively reviewed but was not recompiled here. For a summary of the evidence for recent faulting mapped prior to 1977 see Smith (1977a, b, c, d).

San Cayetano Fault

The pre-1977 literature on the San Cayetano fault indicates that no conclusive evidence for Holocene offset was present but that late Pleistocene? units were offset. Rockwell (1983, Plates 1b, 1c, 1d) has mapped Qf_3 and Qf_4 units (late Pleistocene to Holocene) as being cut by the San Cayetano fault. He also shows alluvium (Qal) and actively eroding slopes (Qog) as being cut by many of the faults on his maps but I assume this is only diagramatic as he makes no mention of this in his text. Since he designates a solid-line fault as either exposed or well-located it is difficult to tell which is the case at any specific location. I will mainly discuss those units mentioned in his text as being cut by the faults.

At the mouth of Sisar Canyon (Plate 2), Rockwell (1983, p. 127-128) says that a remnant of Qf_5 fan surface north of the fault is about 13 m above the present stream level. He estimates this unit to be 15-20 ka (thousands of years) old (p. 127) at this location, but elsewhere (Table

V, p. 71) (see Figure 6, this report) he estimates this unit as 25-30 ka old. This appears to represent the difference between two subdivisions of his Qf_5 unit -- Qf_{5a} (15-20 ka old) and Qf_{5b} (25-30 ka old) -- but he does not subdivide these units on the map at these locations. Keller and others (1981a, p. 80) indicate the terrace surface is 12.2 m above the stream level. Rockwell (1983, Plate 1b) shows a Qf_5 fan segment south of the fault adjacent to a Qf_{3-4} fan segment but Keller and others (1981a, Plate 8) show only Qf_{3-4} fan segment south of the fault in the same location. The younger fan segment is estimated to range from 4-12 ka old, and since it is shown adjacent to the fault, the map certainly implies that the fault is Holocene in age.

About 1 km to the east, at Bear Canyon (Plate 3), an alluvial fan mapped as Qf_4 (Rockwell, 1983, Plate 1c) is offset 9 ± 1 m (p. 128). This fan is estimated to be late Pleistocene or Holocene in age (8-12 ka). This yields a vertical slip rate of 0.65-1.25 mm/yr. Keller and others (1981a, p. 80) say the scarp is only 6.1 m high which would give a vertical slip rate of 0.51-0.76 mm/yr.

Rockwell (1983, Plate 1c) shows the fault as solid southeast of the canyon mouth, along the boundary between rocks of Eocene age and the Qf_4 unit. Most other sources (Smith, 1977c) show this portion of the trace concealed.

Rockwell (1983, p. 131) mentions an exposure in the Silver Thread Oil Field, about 1 km west of Santa Paula Creek (Plate 3), in which bedrock (Monterey Formation) is thrust over colluvium as evidence of late Pleistocene and Holocene activity. No datable material or offset units are present but he (p. 132) bases his estimate of youthful activity on the lack of development of a B horizon in the colluvium.

At Mud Creek, about 4 km east of Santa Paula Creek (Plate 3), Rockwell (1983, p. 135) says that a Q_{5a} age alluvial fan (which he maps only as Qf_5) is apparently offset 32 ± 3 m, and calculates a slip rate of 2.35 ± 0.55 mm/yr. on a fault plain dipping 53°. He also says a Q_3 fan in the same area is not faulted enough to show a recognizable scarp but he shows the fault trace (Plate 1c) as solid across a Qf_3 unit on the map.

At Orcutt Canyon (Plate 3), a Qf_3 age fan is shown by Rockwell crossing the fault (1983, Plate 1c) and he says (p. 135) it appears uncut but that any scarp may be obscured by road or oil-drilling platform construction.

At Timber Canyon (Plate 3), Rockwell (1983, p. 135) says that very recent fan material (mapped as Qf_1 or Qf_2 here) completely buries the fault. He invokes fan segmentation and rapid fan head deposition in this area as suggesting Holocene activity of the fault.

At Boulder Creek (Plate 4), Rockwell (1983, Plate 1d) shows a Qt_3 unit cut by the fault and says (p. 140) there is a questionable 2.5 m scarp. Eastward from Boulder Creek there are no other terrace or fan units crossing the fault but the trace seems to follow a general oversteepening of the slope, as it does throughout its length. This oversteepening may be as significant in suggesting Holocene activity as any of the previous data. However, there seems to be considerable disagreement as to just where the fault is located between the sources summarized by Smith (1977c, Plates 1, 2, and 3) and the traces shown by Rockwell (1983, Plates 1b, 1c, 1d). This discrepancy could not be resolved in this evaluation as it would require a detailed study of the topography and geology along the fault.

Along the stretch of the San Cayetano fault from Snow Canyon to Sespe Creek, Cemen (1977, Plate I) shows the fault as concealed, except for about 1 km from Sespe Creek westward and some inferred traces about 1 to 2 km northeast of Snow Canyon. Smith (1977c, Plate 3) shows the fault as well-defined for about 1 km northeast of Snow Canyon and shows it concealed beyond that. Rockwell (1983, Plate 1d) shows a double trace along this stretch and, for the most part, Cemen's concealed trace is between or coincident with Rockwell's traces.

Arroyo Parida-Santa Ana Fault Zone

Smith (1977d, FER-26) evaluated the evidence for Holocene activity on the Arroyo Parida-Santa Ana fault in the vicinity of the Ventura River and Ojai Valley. For the purposes of this report I will refer to the Arroyo Parida-Santa Ana fault zone by the name Santa Ana fault east of the Ventura River and Arroyo Parida fault west of the Ventura River. Most authors connect these two faults but when replotted on the topographic base (Plate 1) there are a number of disagreements (see also Smith, 1977d, Plate 1). Clark (1982, Plate I) shows the Arroyo Parida fault, west of the Ventura River, along the southern side of a prominent hill in the terrace deposits. Rockwell (1983, Plate 1a) shows the fault along the northern edge of this hill, about 300 m south of Baldwin Road. Clark (1982, Plate I) shows the Santa Ana fault as inferred south of Krotona Hill near Villanova Road. He shows the Villanova fault here as solid (well located) and just south of the Santa Ana fault. However on Plate I of Keller, and others (1981a) Clark shows the Villanova fault and the Santa Ana fault as being connected and as being inferred. Rockwell (1983, Plate 1a) shows both faults as solid and as being connected. He uses this location, where Qt_{6a} terraces (approximately 38 ka old) are displaced and a location west of the Ventura River where Qt_{5b} terraces (approximately 29 ka old) are offset to estimate a constant slip rate of approximately 0.37 mm/yr (see Figure 3). The Qt_{6a} unit is dated at approximately 38,000 y.b.p. (years before present) from a location on similar units to the south. He (p. 69, Table IV) (see Figure 3) shows the 38,000 year old terrace to be offset 14 m by the Santa Ana fault. Farther east, where Clark (1982) shows the fault as buried, Rockwell (1983, Plate 1a) maps the fault as solid through Qt_2 (85-200 y.b.p.) and Qt_3 (500-5000 y.b.p.) units along San Antonio Creek. Neither Smith (1977d) nor Clark (1982) show a surface trace in this location.

Farther east, along the northern flank of Black Mountain, Rockwell (1983, Plate 1b) maps the fault as solid. Smith (1977d, Plate 4) shows the fault, as mapped by Weber and others (1975), with some complications from landsliding. Clark (1982, Plate I) shows the fault as buried and away from the mountain front here from information based on a study of ground water anomalies.

Smith (1977d, Plate 3) shows several north-facing scarps in the vicinity of Meiners Oaks; two short ones are located west of the Ventura River and one, about 1 km long, is located east of the Ventura River along Lomita Avenue. Neither Clark (1982) nor Rockwell (1983) show any faults in this vicinity and Clark (p. 26) says there is no evidence of flexural-slip north of the Santa Ana/Arroyo Parida fault. If these scarps are due to faulting, as shown by Smith (1977b), they would cut Rockwell's Qf_{5a} and Qf_{5b} units suggesting movement since latest Pleistocene (15-30 ka) time.

Oak View Faults

Smith (1977b, Plate 1) plotted and evaluated four of the faults in this group, mainly from Weber, and others (1975). These faults were named by Clark (1982) and are called the Oak View faults in Figure 1. Smith was mainly evaluating the Lion Canyon fault (called Lion fault by Clark, 1982), the Big Canyon fault, and the Sisar fault.

Seven relatively short, south-dipping, high-angle reverse, flexural-slip faults comprise the Oak View faults (Keller and others, 1981a). From north to south these are the Villanova fault, the La Vista fault, the Devil's, Gulch fault, the Oak View fault (2 parallel traces), a short unamed fault, and the Clark fault. Keller and others (1981a) show all of these faults, on a map by Clark (Plate I) and name them on another map (Plate IX) and in the text (Figure 4). Short, inferred traces are shown by Clark (1982, Plate I) between Devil's Gulch fault and northern Oak View fault but are unnamed. These are not included in the original seven because of their limited extent and questionable existence.

The Villanova fault mentioned under the section on the Arroya Parida-Santa Ana fault, either parallels or joins the Santa Ana fault south of Mira Monte. Clark (1982, Plate I) shows the two as separate but Clark's map in Keller, and others (1981a, Plate I) joins the two. Rockwell (1983) essentially follows Keller, and others (1981a) and joins it with the Santa Ana fault. Clark (1982) shows the fault cutting older terrace deposits (Qot) which Rockwell (1983, Plate 1a) delineates as Qt_{5b}, Qt_{6a}, Qt_{6b}, and Qt_{6c}; units which range from 29,700 to 100,000 years before present. The amounts of offsets on late Pleistocene units and the average slip rate (Figure 3) suggests that a Holocene component of offset may be small enough to be undetectable or obscured in the younger units.

The La Vista fault traces, as plotted on Plate 1 from Rockwell (1983) and Clark (1982), show considerably disparity on the location of the northeastern portion of the fault. It may be that both locations are partially correct. They agree on the placement of the southwestern end of the fault although Clark shows the fault both dashed and solid across older alluvium (his Qoa) and solid through Qot. Rockwell (Plate 1a) shows the trace as solid across his Qt_{5b} unit.

The Devil's Gulch fault, as mapped by Clark (1982; Plate I), extends from the Ventura River northeastward to San Antonio Creek. Except for an area near Highway 33, where he maps the fault under a landslide, the fault is shown as a solid line. However on Clark's map in Keller and others (1981a, Plate I) he shows the fault as inferred in the central portion. Rockwell (1983, Plate 1a) shows the fault as solid except near the northeastern end where he shows the trace dotted toward San Antonio Creek. Two traces are mapped by Clark (1982) near Highway 33 where he designates them as the upper (southernmost and stratigraphically higher) and the lower (northernmost) Devil's Gulch fault. The lower Devil's Gulch fault is exposed in a roadcut sketched by Clark (1982, Figure 6). This sketch of the roadcut does not show the true dip (45°) since the angle of the outcrop is about 40° from the strike direction. Rocks of the Modelo Formation are thrust over late Pleistocene terrace gravel for an apparent offset of more than 7 m, south side up (p. 33). The upper Devil's Gulch fault is exposed in a roadcut just east of Highway 33. The fault dips about 35-40° here and Clark (1982, Figure 7) shows a scarp in colluvium and soil; the most significant location suggesting Holocene activity. According to Clark (1982, p. 33) the "A" soil horizon that is faulted is of Holocene age. Minimum apparent displacement of the terrace gravels is about 1.8 m (Clark, 1982, Figure 7); the angle between the road cut (shown in Figure 7) and the strike of the fault is about 30°.

The Oak View fault zone, is mapped as two faults by Clark (1982). At most they are 0.2 km apart. Clark (p. 41) refers to these as a north and south branch because he shows them converging to the east and joining the Lion fault. Rockwell (1983, Plate 1a) does not join these two traces but shows them cutting terrace surfaces in the community of Oak View where Clark (1982, Plate I) shows them as concealed. Clark (1982) shows these faults as solid across the older terrace surfaces on his thesis map but in his earlier version (Keller, and others, 1981a) he shows them as inferred.

Two trenches were dug across the southern Oak View fault by the Earth Technology Corporation (1981) in a study for the U.S. Bureau of Reclamation. Both trench logs, Figure 4 (Trench log 4) and Figure 5 (Trench log 4A), show minor offset in the A soil horizon. Figure 5 shows a B soil horizon truncated and both logs show a fault dipping about 50-55° southeast with rocks of the Monterey Formation to the southwest faulted against terrace gravel of Quaternary age to the northeast, with a minimum dip-slip displacement of about 2.5 m.

The other two faults mapped south of the Oak View fault by Clark are inferred. An unnamed fault is shown on Clark's map in Keller and others (1981a) between the southern Oak View fault and the Clark fault but does not appear on Clark's later map (1982). The Clark fault is shown on both maps but is called the Clark lineament in Clark's thesis (1982, p. 47). Neither the unnamed fault nor the Clark fault are exposed but are mapped from topographic and photographic evidence. Rockwell (1983) shows neither fault.

Two short (about 1 km long), inferred faults are shown by (Clark, 1982, Plate I) between the Devil's Gulch fault and the north branch of the Oak View fault but are not discussed in the text. Rockwell (1983) does not show these faults.

The Lion fault, as mapped along the southern edge of Upper Ojai Valley by Rockwell (1983, Plate 1b), is shown separating Tertiary rocks from a unit designated Qf_{3-4}, probably Holocene in age. Clark (1982) shows this area as complicated by massive landsliding. Trenches dug by Gorian and Associates (1983) indicate possible Holocene displacement along southwest dipping reverse faults but the evidence shown in the trench logs is complicated by what appears to be features which may be due to landsliding.

Orcutt/Timber Canyon Faults

Keller, and others (1981a, p. 66) and Rockwell (1983, p. 169, Figure 37) say there are eight and nine faults, respectively, in this group; Rockwell (1983, Plate 1c) shows 10 on his map. Many are multiple traces in relatively narrow fault zones. Both authors indicate four major fault zones all south of the San Cayetano fault with traces crossing Qf_3 and older units in either Orcutt Canyon, Timber Canyon, or both. All faults show upslope facing scarps, south side up, with displacement on a series of late Pleistocene fan deposits, uplifted and isolated from the present erosional regime. Soil development profiles have been used to identify seven terrace or fan surfaces from historic to perhaps 126,000-200,000 years old.

From north to south, the main faults are called the Thorpe, Orcutt, Culbertson, and Rudolph faults (Plates 3 and 4). Rockwell (1983) has only a general discussion of these faults but summarizes the offsets of three of the faults in his Table V (see Figure 6, this report). These faults are all interpreted as flexural slip, bedding plane faults. Rockwell (1983, p. 172) says the Timber Canyon fan surface (Holocene Qf_3 unit, 500-5000 years old) is warped or offset by the Thorpe, Culbertson, and Rudolph faults. Late Pleistocene fan surfaces have significant scarps ranging from 4.5 to 98 m (see Figure 6). The faults show normal displacement where bedding is overturned or reverse displacement where bedding is right side up (Keller and others, 1981a, p. 66) suggesting a relationship interpreted as indicating flexural slip along bedding planes. The older terraces are progressively more tilted toward the south proportional to age. Keller and others (1981a) assume that the rate of folding, and hence of faulting on bedding planes has been relatively constant. They plot displacement against time and tilting against time to interpolate ages of undated surfaces from limited locations where dated units have been found. The estimated ages of the older surfaces projected by Keller and others (1981a, Table 1) do not agree with estimated ages projected by Rockwell (1983, Table V). Figure 6 shows both of these tables for comparison. Rockwell (1983, p. 72) bases his age estimates of surfaces in this area on a radiocarbon date from the Qf_3 surface and the similarity of his Qf_6 surface to a marine terrace dated at 80 to 105 ka old. Keller and others (1981a, p. 69) base their age estimates on the same radiocarbon date on the Qf_3 surface and a date from a Qf_6 unit near Ojai of about 38 ka. Slip rates from Keller and others (1981a) are, of course, reasonably constant but rates calculated from Rockwell's data (1983) vary considerably on each fault. Rockwell and others (1984, Table 2) show the same age estimates as Rockwell (1983) but they do not list the older Qt_7 surface so the total age range of these units is apparently in some doubt.

Smith (1977a, Plate 3) shows faults mapped by Weber (1975) and some scarps mapped by himself and not shown by Weber or Rockwell (1983). Smith classified these as displacing late Pleistocene or Holocene (?) deposits but some of the locations are at variance with faults shown by Rockwell (1983). Only selected traces from Smith (1977a) are shown on Plate 3 because many of the traces shown by Rockwell (1983) appear to cross those shown by Smith. Diagramatically they are essentially the same.

FIELD AND AIR PHOTO OBSERVATIONS

Limited field observations were made in the Oak View area, the Timber Canyon area, and the western end of the San Cayetano fault. Access to the San Cayetano fault east of Santa Paula Creek and to Orcutt Canyon was not possible due to locked gates on private land and lack of sufficient time to identify and contact landowners for permission to enter. Air photos were used both in the field and in the office to identify areas where fault traces are well-defined. USDA (1953, AXI) photos covered the entire area and USGS photos cover portions of the area; Flight GS-VBUK (1967) covers the area west of Orcutt Canyon and Flight GS-VCHC (1969) covers part of the area east of Orcutt Canyon.

Many of the terrace or fan surfaces upon which the soil development data was gathered appear to have been eroded, after deposition, to various degrees. This suggests that the ages of some of the units may be older than that estimated from the soil development. This will not affect the correlation of surfaces but may add significantly to the range of slip rates calculated. Since a constant slip rate is assumed on the Arroyo Parida-Santa Ana fault zone (Rockwell, 1983), from which age estimates of other surfaces are interpolated, broad limits may be assumed for both surface ages and slip rates. Limited data on the thickness of fan or terrace units is given by Rockwell (1983) or Keller and others (1981a). The base of these units could be mapped, and thicknesses compared to soil development and surface offsets to further substantiate age estimates of these surfaces.

San Cayetano Fault

At the mouth of Sisar Canyon Rockwell (1983, p. 128) assumes a dip of 45° (constrained by subsurface information) on the fault and calculates a slip rate of 0.85-1.25 mm/yr (Plate 2). He also states that a Q_5 surface 13 m above the present stream level is 15,000-20,000 years old. The fault scarp here is too straight to dip 45° (more like 75-80°) which suggests that the fault is more complicated than shown here and that the present scarp may be a secondary fault related to a buried trace under the fan. A more sinuous trace through older terrace gravel (Qf_7 of Rockwell) which branches from the trace mapped by Rockwell is visible on air photos about 0.3 km west of Sisar Canyon. This fault scarp was recognized by Smith (1977c) and was shown by Keller and others (1981a, Plate VIII) on a map compiled by Rockwell. On his later map, however, Rockwell (1983, Plate 1b) does not show this fault but instead maps a contact between his Qf_7 and Qf_5 units. In the field this is a well-defined scarp with a slope that varies from 20-30° and is about 6 m or more above the Qf_5 surface.

At Bear Canyon (Plate 3), where Rockwell (1983, p. 128) discusses some of the best evidence of Holocene offset (i.e. Qf_4 surface offset 9 ± 1 m), the scarp is quite straight and steep west of the canyon but becomes less distinct or partially burried east and southeast of the active channel.

An exposure in the Silver Thread oil field (Plate 3) is cited by Rockwell (1983, p. 131) as having Monterey Formation thrust over colluvium with no B horizon soil development. I question these conclusions for two reasons. Thrust faults commonly have a wedge of colluvial-like material accumulated under the "leading edge" of the fault plane. This material, a fragmental fault breccia, is mixed with colluvial debris and is soft and easily erodable, obscuring or modifying soil development. Repeat movement on the fault tends to mix and soften this wedge even further.

At Mud Creek (Plate 3), where Rockwell (1983, p. 135) cites a 32 ± 3 m scarp in Q_{5a} material, it appears on air photos that the Q_{5a} (which he maps as Of_5) unit south of the fault may be a landslide or slump block. This is further substantiated by an antislope fault or slide fracture across the top of the unit. Smith (1977c, Plate 2) also suggests a landslide here. Displacement on the antislope fault or fracture would also make the offset suspect and complicate the slip rate calculation.

In the next tributary to the east, Rockwell (1983, Plate 1c) maps a solid trace across a Qf_3 unit but says the unit is not offset. This unit appears to have a constant slope but the surface north of the fault seems to be higher than the surface south of the fault when viewed on air photos. I was not able to reach this area to verify this in the field.

At Timber Canyon (Plate 3), Rockwell (1983) estimates offset and slip rate on projected profiles of active portions of the Timber Canyon fanhead (Qf_1). He cites fanhead deposition and fan segmentation as strong evidence for Holocene activity.

The Timber Canyon fan is the only one along this stretch of the fault which has such young appearing deposition (Plate 3). If it were caused by tectonic uplift the same phenomena should occur in other canyons nearby but this is not the case. What appears to be a possible large landslide occurs above the most active fanhead branch and may be contributing to the rapid deposition. This source of debris may be more susceptible to erosion than adjacent areas. Even though the landsliding is probably related to tectonic processes, the fact that the fanhead here is very active cannot be solely ascribed to tectonic uplift. Rockwell (1983) uses fan profiles and inferred ages to estimate a 16-20 m dip slip here which yields a slip rate of 3.2-4.0 mm/yr. If the fan accumulation is mostly controlled by erosional oversupply, these high rates may be quite misleading. A rate of 3.2 mm/yr. could be expected to develop a scarp 35 m high if faulting occurred during Holocene time which should still be partly evident. Rockwell (1983, Plate 1c) shows the fault as buried across the fanhead but previous mapping reviewed by Smith (1977c) shows the fault to be located at the uppermost part of the fan. This alluvial fan does not appear to be offset at all on the air photos.

At Boulder Creek (Plate 4) where Rockwell cites a 2.5 m scarp in Q_3 material (1983, p. 140) no scarp, or warp, or differential erosion is evident on the air photos.

Arroyo Parida-Santa Ana Fault Zone

South of Mira Monte along Villanova Road (Plate 1), Rockwell (1983, p. 68) uses offset terrace deposits, correlated with dated terrace deposits in the same general area, to estimate a constant slip rate of 0.37 mm/yr. He says a Qt_{6a} surface is offset 14 m here. I can see no well-defined scarp where he shows the Qt_{6a} unit as being cut (Plate 1a) although an erosionally modified hill is visible which he interpreted as a fault.

Near San Antonio Creek, where Rockwell (1983, Plate 1a) shows the fault cutting Qt_2 and Qt_3 units, I can see no evidence of even a poorly defined fault. Clark (1982, Plate I) shows the fault as concealed and no evidence was seen by Smith (1977d). Rockwell makes no mention of these units being offset or of the fault being exposed here in his text. This location would demonstrate significant Holocene activity if the younger units were cut but, without supporting data, must be rejected.

Farther east, along the northern flank of Black Mountain (Plate 2), no well-defined trace could be seen on air photos. I therefore concur with Smith's (1977d) conclusion that the fault may be late Pleistocene but Holocene activity cannot be substantiated.

A short, north-facing scarp just west of the Ventura River may be fault-controlled or may be an erosional feature. Rockwell (1983, Plate 1a) places the Arroyo Parida fault along this scarp and indicates the offset unit to be the Qt_{5b} terrace. It is not clear if the younger Qt_{5a} terrace immediately to the east is offset. No evidence of recent faulting was noted on air photos in the bedrock to the west or in the Holocene river deposits to the east.

Oak View Faults

Smith (1977b) evaluated the Lion Canyon, Big Canyon, and Sisar faults with the unnamed faults of the Oak View area. No significant new data have been developed for the Big Canyon or Sisar faults so no further evaluation was attempted. The Lion fault was trenched by Gorian and Associates (1983). Offset of presumed Holocene units was found which may be due to faulting but it was not clear whether the evidence shown on the trench logs was due to fault activity or landsliding or both. Smith

(1977b) concluded that many of the scarps in this area could be entirely erosional and are complicated by landsliding. I reviewed air photos covering these faults and found no reason to disagree with Smith's conclusions. The Oak View faults (Plate 1) are reevaluated below.

The Villanova fault is considered here to be as mapped by Clark (1982, Plate I), separate from the Santa Ana fault. A steep, possibly multiple, north-facing scarp, which may be in excess of 30 m high, lies just south of Villanova Road. South of Villanova road both faults may be coincident but, since the Santa Ana fault is not well-defined and is obscure elsewhere, I consider this as all part of the Villanova fault, mainly for convenience.

From an inspection of air photos and limited field observations, I believe the Villanova fault does displace the Qt_{5b}, Qt_{6a}, Qt_{6b}, and Qt_{6c} surfaces as mapped by Rockwell (1983, Plate 1a). No evidence for Holocene activity has been observed here, but the fact that the north-facing fault scarp appears to offset a Qt_{5b} surface, which dams Mirror Lake, and that younger alluvium appears to be accumulating here is considered strong evidence for post-Qt_{5b} activity.

The hillside south of Villanova Road may be a composite reverse fault with several traces. On air photos this hillside is a scarp-like feature with anomalous, superimposed bench-like features which appear to be somewhat sinuous. These could mark the trace or traces of a relatively high-angle reverse fault and they appear to be continuous with the trace of the fault to the southwest.

A very short, north-facing scarp, possibly an extension of the Villanova fault occurs west of the Ventura River. This scarp may offset Qt_{5a} terrace deposits but was not mapped by either Clark (1982) or Rockwell (1983). It appears to be tectonic rather than erosional.

The La Vista fault is fairly well-defined, though possibly enhanced by erosion, in its central portion. The northeastern part of the fault appears to be a composite, north-facing scarp and may include the disparate locations of both Clark (1982) and Rockwell (1983). Clark places a concealed trace at the base of the scarp and Rockwell shows a trace part way up the hillside. The existence of linear irregularities along the hillside here suggests that both interpretations may be correct.

The Devil's Gulch fault appears to be a composite zone with two or more planes of movement. Two exposures along Highway 33 show bedding-plane faults in rocks of the Monterey Formation. The northernmost fault offsets late Pleistocene terrace gravel and an exposure on the southernmost fault is shown by Clark (1982, Figure 7) to have a scarp in alluvium. I could not see this evidence, but along the projection of this trace to the northeast, near the top of the composite scarp, a linear zone of oversteepened slope (bench ?) was observed which may represent recent movement on this portion of the fault zone. This anomalous slope feature, which appears to be associated with minor landslides and a concentration of moisture-dependent vegetation, could not be followed more than a few tens of meters. On projection to the southwest, a bedding-plane fault is visible along Highway 33 where the dip is about 30° to the southeast.

The Oak View fault zone consists of two fairly well-defined, erosionally modified, fault scarps which face northwest and offset tilted terrace surfaces mapped as Qt_{6b} by Rockwell (1983, Plate 1a). He also shows both traces as cutting Qt_{6a} and Qt_{5b} units to the southwest through Oak View. I could see no evidence for these extensions either on air photos or in the field. Clark (1982) also shows both faults concealed across these surfaces.

Neither the Clark fault or other, short, inferred faults shown by Clark (1982) could be seen on air photos or in the field.

North of the projected connection of the Arroyo Parida-Santa Ana faults two other short scarps are visible on air photos (Plate 1). These appear to be flexural slip faults also, with the south side up. One is just south of Meiners Oaks along Lomita Avenue and trends east-west to the terraces along the Ventura River near Rice Road. The other is on the west side of the Ventura River. These two faults may connect but they are not well aligned and no evidence of faulting was seen in the river channel except a very weak vegetation alignment. These faults are well-defined where mapped but could not be traced beyond the locations shown on Plate 1. The fault traces were previously mapped by Smith (1977d).

Orcutt/Timber Canyon Faults

Most of the evaluation of these faults is based on air photo interpretation, the work of Smith (1977a), and the most recent mapping by Rockwell (1983). Access to the area was limited to the Timber Canyon area. I question the location of many of the fault traces by Rockwell (1983, Plate 1c) and in most cases agree with Smith (1977a).

The Thorpe fault is well-defined by north-facing scarps across Rockwell's (1983, Plate 1c) Qf_5 surfaces in Orcutt Canyon, less well-defined across the ridge between Orcutt and Timber Canyons, and reasonably well-defined across the Holocene Qf_3 surface in Timber Canyon. The fan surface in Timber Canyon does not appear to be offset on the photos or in the field. However, it is probably warped or may be uplifted enough to have caused significant deepening of the gullys south of the projected trace of the fault. I can see no evidence for extending this fault eastward beyond Timber Canyon or westward beyond the fan deposits in Orcutt Canyon.

The Orcutt fault consists of two well-defined, north-facing scarps across older fan surfaces (Of_{7a}) on the ridge equidistant between Orcutt Canyon and Santa Paula Creek; about 1.5-2.0 km southwesterly from Orcutt Canyon. Less well-defined evidence extends eastward to the east side of Orcutt Canyon. Rockwell (1983, Plate 1c) shows his Qf_5 unit cut by the fault in Orcutt Canyon but I could see no evidence for this on air photos. The fault can be inferred to extend to Orcutt Canyon from anomalous topography. The fault does not appear to extend to Timber Canyon.

The Culbertson fault is well-defined by a north-facing scarp displacing Qf_{7a} surfaces further south across the same ridge where the Orcutt fault is most evident; about 1 km southwesterly from Orcutt Canyon. It is also well-defined across the Qf_3 fan surface in Timber Canyon where the south side is higher and more deeply gullyed. Rockwell (1983, Plate 1c) maps the trace across the Timber Canyon fan somewhat more southerly than I do. I concur with Smith (1977a) as to where the scarp appears to offset the fan on air photos. I cannot see any evidence for connecting the two well-defined segments as Rockwell (1983) does other than that they appear aligned.

The Rudolph fault has four, parallel, well-defined, north-facing scarps across a Qf_{6c} surface immediately to the west of Orcutt Canyon. Rockwell (1983, Plate 1c) shows only three traces here and shows them also cutting a Qf_5 surface in Orcutt Canyon. Only one, the northernmost, appears to cut this Qf_5 surface with a north-facing scarp. This trace appears to extend eastward about 1 km but is less well-defined. I could see no evidence for extending this fault to Timber Canyon as Rockwell does. There is no evidence of it crossing the Timber Canyon fan; no differential gullying or apparent mismatch of surface slope. There is a slight suggestion that the fan may be higher to the north of where Rockwell projects the fault but this would represent a reversal of movement. This could be caused by depositional processes alone.

Other faults in the area were neither well-defined nor long enough to warrant any evaluation other than an air photo inspection.

CONCLUSIONS

The relationship between activity on the San Cayetano fault, the deformation of the Ventura Basin, and the activity on faults of the two groups of presumed flexural slip faults evaluated here is not clear. It is reasonable to assume that a relationship does exist and that movement on the flexural slip faults may be keyed to movement on the San Cayetano fault or at least on the tectonic deformation which seems to be transversely shortening the Ventura Basin. If true this suggests that movement is not going to occur on the San Cayetano fault without having some significant affect on the flexural slip faults. The converse is probably not true but cannot be ruled out. Therefore, I conclude that these fault systems are related and cannot be separated as far as evidence to support the concept of sufficiently active (Hart, 1985, p. 5) is concerned. If a few faults show evidence of being active in Holocene time they probably all are.

The concept of well-defined (Hart, 1985, p. 5) adds a different dimension to the problem of deciding whether and where faults should be zoned. My understanding of subsidiary faults, which we may assume the flexural slip faults to be, is that they may not persist for any significant length and that they tend to produce surface rupture precisely where previous rupture has occurred. On this basis the flexural slip faults should only be reactivated where they are well-defined.

San Cayetano Fault

The evidence for late Pleistocene to Holocene activity on the San Cayetano fault at Bear Canyon is compelling. The evidence is less definite elsewhere but still suggests possible Holocene activity. On the ridge east of Santa Paula Creek above the fault trace several well-defined antislope faults look very recent on air photos. West of Sespe Creek, also above the probable trace of the fault, another antislope fault is visible on air photos. The origin of antislope faults is not well understood but their relationship to major fault zones, particularly thrust faults, is well established. The freshness of these features along the San Cayetano fault suggests recent activity. Even more compelling, to me at least, is the consistent oversteepening of slopes above the mapped trace of the fault. This criterion is the basis used for mapping the fault where good exposures are not evident.

Arroyo Parida - Santa Ana Fault Zone

The evidence suggesting Holocene or even late Pleistocene activity on the Arroyo Parida - Santa Ana fault zone is mostly indirect or ambiguous. Ground water anomalies and landslides obscure the interpretation and placement of the fault. The diverse locations of the fault, as plotted by various authors, is not only an indication of different interpretation but also is an indication of the lack of definition of the fault as a continuous, mappable feature. With the exception of the short, north-facing scarp just west of the Ventura River, I conclude that the fault is neither sufficiently active nor well-defined.

Oak View Faults

The evidence for Holocene activity on the Oak View faults is limited to the Devil's Gulch fault where Holocene soil and colluvium is said to be offset (Clark, 1982, Figure 7 and p. 33), and to the southern Oak View fault where trenches dug across the fault also suggest Holocene activity (see Figures 4 and 5). All of the faults are well-defined by north-facing, probably composite scarps, at least along portions of their traces. Although the Villanova, La Vista and northern Oak View faults displace only late Pleistocene units, Holocene activity is presumed since all of the well-defined portions of these faults appear to be physiographically similar to those faults where Holocene activity has been demonstrated. Therefore, if one is active they all must be assumed to be active. The Clark fault and various unnamed faults both north and south of the Oak View faults are not well-defined and are either inactive or have a very low Holocene slip-rate.

The scarps near Meiners Oaks are well-defined and as fresh as the rest of the Oak View faults. They could be erosional features, but this seems unlikely because of their orientation and location. They appear to be offset units of latest Pleistocene age. Although Holocene activity cannot be demonstrated, the faults are at least as active as some of the other faults in the Oak View fault group.

Orcutt/Timber Canyon Faults

The most convincing evidence for Holocene activity in this group of faults is the modification or offset of the Holocene Qf_3 surface in Timber Canyon by the Culbertson and Thorpe faults. Short portions of these faults, as mapped by Rockwell (1983, Plates 1c and 1d) are well-defined. Others, such as the Orcutt and Rudolph faults, are well-defined but appear to offset only older units. No evidence for faulting is visible on air photos between well-defined traces or projected beyond them. Some places are badly eroded and faults could be present but obscured. Without sufficiently detailed mapping to define the faults where they have been inferred, they can only be zoned where they are well-defined.

RECOMMENDATIONS

Since two basically different types of faults are being considered here, different approaches are required. The San Cayetano is a major, primary, earthquake-producing, thrust fault and should have multiple branches and subsidiary faults associated with it. The flexural-slip faults are essentially subsidiary, bedding plane faults that are not considered to be sources of damaging earthquakes (Yeats, and others, 1981).

San Cayetano Fault

There is considerable disagreement on where to map the fault trace at many locations along the San Cayetano fault. Where this could not be resolved multiple traces should be shown. This is probably a better approach anyway because thrust faults tend to have multiple traces which may not always be evident.

The San Cayetano fault should be zoned continuously with a fairly wide zone, from the vicinity of Wilsie Canyon, eastward across Santa Paula Creek, along the south flank of Santa Paula Ridge to Sespe Creek. The zone should be wider where the trace is mapped at different positions by different authors, or where multiple strands have been mapped.

Antislope scarps are present in two places in the upper plate. About 1-2 km east of Santa Paula Creek on the southeast flank of Santa Paula Ridge and about 2 km west of Sespe Creek. The zones should be drawn to encompass these features. Some antislope faults occur on the lower plate near Mud Creek. They are probably related to landsliding but may also be tectonically enhanced. A few of the major ones should be included in the zone. Recommended zoning is shown on Figures 8, 9, 10, and 11, on which faults traces are identified by color, as to the source used.

Arroyo Parida - Santa Ana Fault Zone

The short scarp, along which Rockwell (1983) mapped the Arroyo Parida fault west of the Ventura River and south of Baldwin Road, appears to be as fresh as the other flexural-slip faults. The other segments of the fault to the west and east are not well-defined. Zoning is recommended only for the well-defined scarp, as shown on Figure 7.

Oak View Faults

The Oak View faults are considered to be flexural slip faults. The Villanova, La Vista, Devil's Gulch, and both Oak View fault traces should be zoned. Narrow zones are recommended because of the bedding plane nature of the faults. The zones should not extend beyond the locations where the faults are well-defined.

The Villanova fault presents a special case because part of what I feel should be zoned has been called the Santa Ana fault by others. Since the Santa Ana fault is generally not well-defined, and may not in fact exist here, I recommend zoning the scarp along Villanova road south of Mira Monte as part of the Villanova fault. Recommended zoning is shown on Figure 7, and should include the short, north-facing scarp west of the Ventura River.

The traces seen on air photos near Meiners Oaks also appear to be flexural slip faults, suggesting narrow zones. See Figure 7 for recommended zoning.

Orcutt/Timber Canyon Faults

The faults of this group seem to be flexural slip faults also and should be zoned with appropriately narrow zones. None of these faults should be zoned beyond where they are well-defined or can be inferred from anomalous topography, nor should they be zoned between aligned well-defined traces. The Thorpe fault should be zoned from Orcutt Canyon to Timber Canyon but not beyond. The Orcutt fault should be zoned from about 2 km west of Orcutt Canyon to slightly east of Orcutt Canyon. The Culbertson fault should be zoned for a short segment west of Orcutt Canyon and where it is well-defined across Timber Canyon but not between these traces. The Rudolph fault should be zoned at Orcutt Canyon and for about 1 km east of Orcutt Canyon but not to or across Timber Canyon. Recommended zoning is shown on Figure 10, and the faults are mostly plotted from air photo interpretation to eliminate the problems caused by differences in location by various authors.

Reviewed; recommendations approved
Earl W. Hart
11/10/85

James E. Kahle

James E. Kahle
Associate Geologist
CEG #709
November 6, 1985

REFERENCES CITED

Cemen, Ibraham, 1977, Geology of the Sespe-Piru Creek area, Ventura County, California: Unpublished M.S. thesis, Ohio University, 69 p., 23 plates, scale 1:24,000.

Clark, M.N., 1982, Tectonic geomorphology and neotectonics of the Ojai Valley and upper Ventura River: Unpublished M.S. thesis, University of California, Santa Barbara, 77 p., 5 plates, scale 1:24,000.

Earth Technology Corporation (ERTEC), 1981, Seismotectonic study for Casitas Dam and vicinity, Ventura County, California: Report prepared for U.S. Bureau of Reclamation, Contract No. 1-07-DV-0112, Ertec Project No. 81-159, 96 p., 7 plates, scale 1:12,000.

Gorian and Associates, 1983, Geologic investigation of the Lion fault, upper Ojai Valley (Ventura County), California: Report for Richard S. Gould, M.D., Work Order No. 1204-1-15, 8 p., 10 plates.

Hart, E.W., 1985, Fault rupture hazard zones in California: California Division of Mines and Geology, Special Publication 42, Revised 1985, 24 p.

Keller, E.A., D.L. Johnson, M.N. Clark, and T.K. Rockwell, 1981a, Tectonic geomorphology and earthquake hazard, north flank, central Ventura Basin, California: U.S. Geological Survey Open-File Report 81-376, 167 p., 9 plates, scales 1:24,000 and 1:31,680. Also released (1980) as Final Technical Report to U.S. Geological Survey, Contract No. 14-08-0001-17678.

Keller, E.A., D.L. Johnson, T.K. Rockwell, M.N. Clark, and G.R. Dembroff, 1981b, Quaternary stratigraphy, soil geomorphology and tectonic geomorphology of the Ojai-Santa Paula area, California, in Quaternary stratigraphy, soil geomorphology, chronology and tectonics of the Ventura, Ojai and Santa Paula areas, western Transverse Ranges, California: Friends of the Pleistocene Guidebook, part I, p. 1-125.

Keller, E.A., T.K. Rockwell, M.N. Clark, G.R. Dembroff, and D.L. Johnson, 1982, Tectonic geomorphology of the Ventura, Ojai and Santa Paula areas, western Transverse Ranges, California in Neotectonics in southern California: Geological Society of America Guidebook, 78th Annual Meeting, Cordilleran Section Meeting, Anaheim, California, p. 25-42.

Rockwell, T.K., 1983, Soil chronology, geology, and neotectonics of the north central Ventura Basin, California: Unpublished Ph.D. Dissertation, University of California, Santa Barbara, 424 p., 6 plates, scale 1:24,000.

Rockwell, T.K., E.A. Keller, M.N. Clark, D.L. Johnson, 1984, Chronology and rates of faulting of Ventura River terraces, California: Geological Society of America Bulletin, v. 95, no. 12, p. 1466-1474.

Smith, T.C., 1977a, The Culbertson, Orcutt, Steckel, Thorpe, and related faults: California Division of Mines and Geology, Fault Evaluation Report 18, unpublished, 11 p., 3 plates, scale 1:24,000.

Smith, T.C., 1977b, The Lion Canyon, Big Canyon, Sisar, and related faults near the Ojai and Upper Ojai Valleys: California Division of Mines and Geology, Fault Evaluation Report 29, unpublished, 9 p., 3 plates, scale 1:24,000.

Smith, T.C., 1977c, The San Cayetano fault: California Division of Mines and Geology, Fault Evaluation Report 19, unpublished, 16 p., 4 plates, scale 1:24,000.

Smith, T.C., 1977d, The Arroyo Parida fault (eastern segment) and the Santa Ana fault: California Division of Mines and Geology, Fault Evaluation Report 26, unpublished, 12 p., 4 plates, scale 1:24,000.

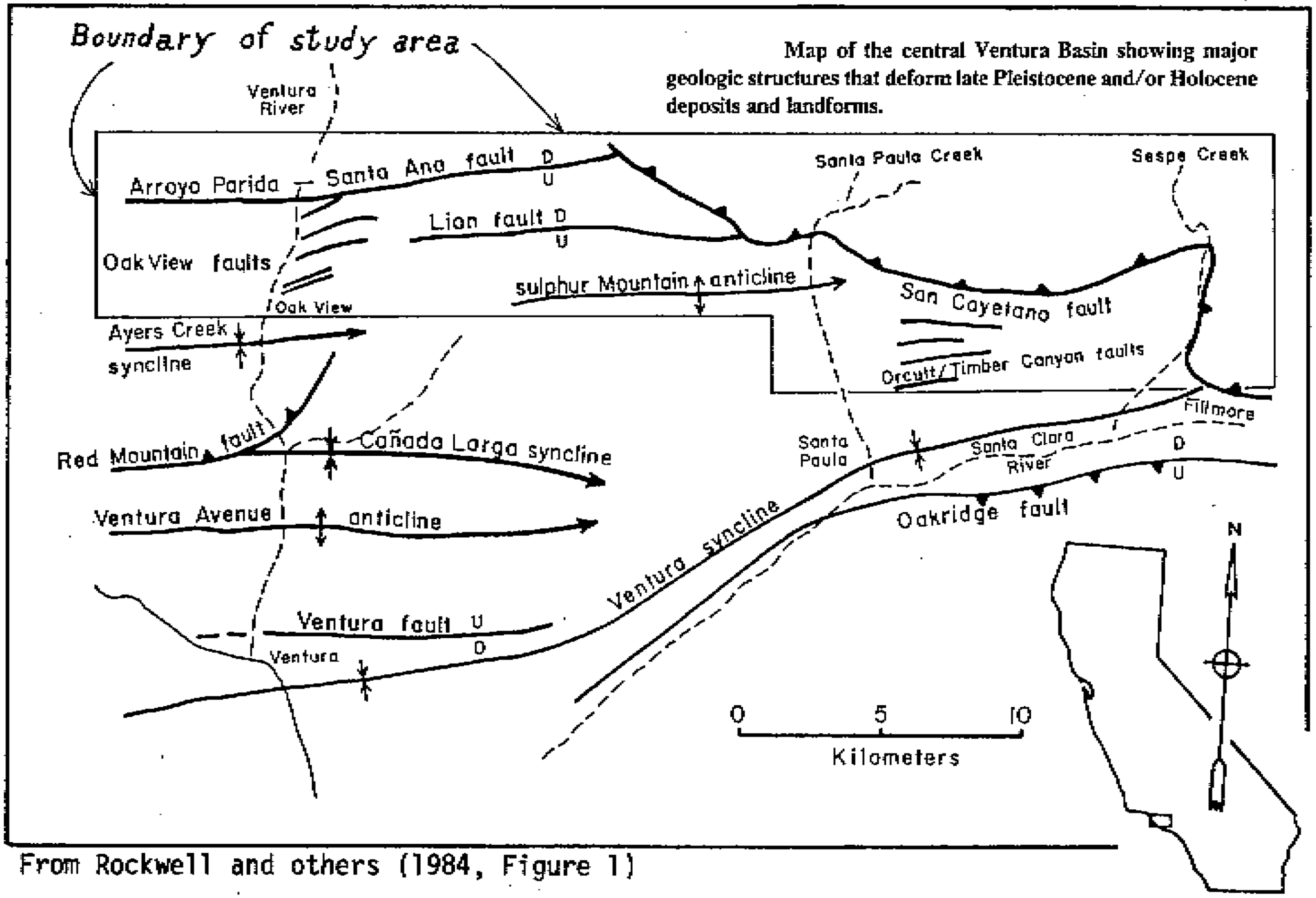
U.S. Department of Agriculture (USDA), 1953, Aerial photography: Flight AXI, Flown 1952-1953, scale approximately 1:20,000.

U.S. Geological Survey (USGS), 1967, Aerial photographys: Flight GS-VBUK, Flown August 12-13, 1967, scale approximately 1:34,000.

U.S. Geological Survey (USGS), 1969, Aerial photographys: Flight GS-VCHC, Flown July 25, 1969, scale approximately 1:33,000.

Yeats, R.S., M.N. Clark, E.A. Keller, T.K. Rockwell, 1981, Active fault hazard in southern California: Ground rupture versus seismic shaking: Geological Society of America Bulletin, v. 92, no. 4, part I, p. 189-196.

Weber, F.H., Jr., E.W. Kiessling, E.C. Sprotte, J.A. Johnson, R.W. Sherburne, and G.B. Cleveland, 1975, Seismic hazards study of Ventura County, California: California Division of Mines and Geology, Open File Report 76-5 LA, 396 p., 9 plates, scale 1:48,000.



From Rockwell and others (1984, Figure 1)

Figure 1 (FER-174). Index map showing general location of faults evaluated and selected geographic features.

Table II. MEASURES AND INDICES OF RELATIVE AGE OF THIRTY SOIL PROFILES

Geomorphic Surface		Classification	Brightest moist mixed color in B horizon: Hue	Chroma	Color Index[1]	Clay[2] XB/XA	Clayfilm Index[3]	Estimated age in years before present (BP)
Qt_1	Car body	Xerofluvent	AC profile, no B horizon			No B	0	10-20
Qt_2	Sespe	Fluventic Haploxeroll	AC profile, no B horizon			No B	0	85-200
Qt_3	Orcutt 0	Pachic Xerumbrept	10 YR	3	4	0.6	0	500-5,000[5]
Qt_4	Orcutt 1	Typic Argixeroll	10 YR	4	5	1.3	3.0	8.000-12,000[6]
Qt_{5a}	Honor Farm	Typic Argixeroll	10 YR	4	5	ND	4.0	15,000-20,000[7]
Qt_{5a}	Shell 2	Typic Argixeroll	10 YR	3.5	4.5	ND	4.5	15,000-20,000[7]
Qt_{5b}	Orcutt 2	Mollic Haploxeralf	10 YR	4	5	1.1	6.0	25,000-30,000[6]
Qt_{5b}	Bankamericard	Typic Argixeroll	10 YR	4	5	ND	7.0	29,000[7]
Qt_{6a}	Oak View[10]	Mollic Palexeralf	7.5 YR	5	7	1.4	7.25	38,000[8]
Qt_{6b}	Apricot	Mollic Palexeralf	7.5 YR	6	8	1.5	5.5	54,000 ± 10,000[9]
Qt_{6c}	La Vista[10]	Typic Palexeralf	7.5 YR	7	9	1.6	7.0	92,000 ± 13,000[9]
Qt_{6c}	Orcutt 3	Typic Palexeralf	5 YR	4	6	1.6	7.5	80,000-100,000[6]
Qt_7	Timber Canyon 4	Typic Palexeralf	5 YR	6	9	ND	8.0	160,000-200,000[6,11]

Figure 2 (FER-174). Table II from Rockwell (1983) showing soil characteristics and estimated ages of terrace units.

Table II. Continued

[1]Color index is computed by adding chroma number to hue (of moist mixed sample), where 10 YR = 1, 7.5 YR = 2, 5 YR = 3. Indices from different profiles on same geomorphic surface are averaged. To determine color, a large air-dired bulk sample was passed through a 2 mm sieve, then fractionated in a mechanical splitter, moistened, hand homogenized to a putty consistency and rolled to a sphere; the latter was then pulled into halves, and color noted from one freshly broken surface.

[2]Ratio of the mean percent of clay in B horizon to that in the A horizon (computed from particle size graphs (Keller and others, 1980).

[3]This index is based on clay film information contained in the profile descriptions and is computed by adding the percent frequency of clay film occurrence to their thickness, as follows: Percent frequency, very few = 1, few = 2, common = 3, many = 4, continuous = 5; Thickness, thin = 1, moderately thick = 2, thick = 3. For example, in the B22t horizon of La Vista 2 there are "... many to continuous (4.5) moderately thick and thick (2.5) clay films..." The index would be 7.0.

[4]This age is based on the inclusion of an abraded brick fragment in the C horizon of the Qt_2 soil at Sespe Creek. A photograph taken in 1893 shows that the terrace was already present.

[5]This age estimate is collectively based upon tree rings of a number of mature oaks growing upon the Orcutt 0 surface, the degree of soil profile development, and a ^{14}C date (see Timber Canyon 1 profile description) on charcoal collected from a presumed buried soil in the lower part of the Timber Canyon profile.

[6]Age estimate based in part upon relative amount of displacement on flexural-slip faults between older surfaces in Orcutt and Timber Canyons, and one ^{14}C date. Also based upon soil correlation to well dated soils along the Ventura River.

[7]Age based on ^{14}C dates from correlative terraces along the lower Ventura River.

[8]Based on two ^{14}C dates on charcoal collected at the base of the Oak View Terrace below Oliva 1.

[9]Age based upon relative amount of displacement on the Arroyo Parida fault.

[10]These measures were taken from the buried soil portion of the profile; only the buried soil portion of the profiles of Oliva 1 and La Vista 3 are correlated to the Qt_6 geomorphic surfaces.

[11]Older and more developed soils grouped with Qt_7 have been sampled and described. Thus, a 160,000 age estimate is a minimum for Qt_7 soils, but appears correct for Timber Canyon 4 as discussed above.

Figure 2 (FER-174). Continued.

Table IV SLIP RATES FOR FAULTS IN THE OAK VIEW AREA

Faulted Geomorphic Surface

Units offset	*(Qt_{5b})*		*(Qt_{6a})*		*(Qt_{6b})*		*(Qt_{6c})*	
FAULT	29,700 yrs.[1] $\pm$ 1250		38,000 yrs.[2] $\pm$ 1500		54,000 yrs.[3] $\pm$ 10,000		92,000 yrs.[3] $\pm$ 13,000	
	Dv[4]	Rv[5]	Dv	Rv	Dv	Rv	Dv	Rv
Arroyo Parida-Santa Ana[6]	11 $\pm$0.3	0.37 $\pm$0.02	14 $\pm$0.3	0.37 $\pm$ 0.02	20 $\pm$ 3	ND[9]	34 $\pm$ 3	ND[9]
Villanova[7]	9 $\pm$0.3	0.30 $\pm$0.02	11 $\pm$0.3	0.29 $\pm$ 0.02	ND[8]	ND[8]	ND[8]	ND[8]
La Vista[7]	11 $\pm$0.3	0.37 $\pm$0.02	15 $\pm$0.3	0.39 $\pm$ 0.02	41 $\pm$ 3	0.76 +0.24 -0.17	98 $\pm$ 3	1.07 +0.20 -0.17
Devil's Gulch[7]	ND[8]	ND[8]	18 $\pm$0.3	0.47 $\pm$ 0.02	37 $\pm$ 3	0.69 +0.24 -0.16	ND[8]	ND[8]
Oak View[7]	ND[8]	ND[8]	ND[8]	ND[8]	19 $\pm$ 3	0.35 +0.15 -0.10	ND[8]	ND[8]

1) Based on ^{14}C date

2) Based on approximate average of two ^{14}C dates and their errors

3) Estimated - Based on rate of displacement of 0.37 $\pm$ 0.02 mm/yr. for the Arroyo Parida-Santa Ana Fault during the last 38,000 yrs.

4) Dv = vertical displacement (meters) from topographic maps (Qt5b $\pm$ 0.3 m, Qt6a, b, c $\pm$ 3m)

5) Rv = vertical-slip rate (mm/yr.)

6) Fault that cuts section

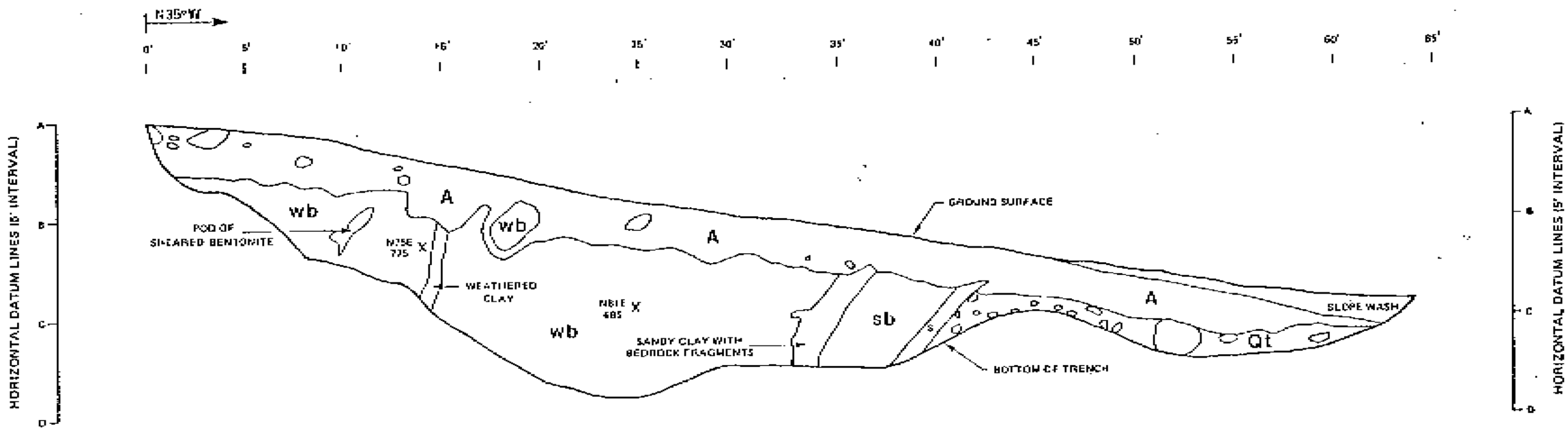
7) Flexural-slip fault

8) ND = Not determined: field evidence insufficient to estimate vertical displacement

9) ND - Not determined: slip rate is assumed to be 0.37 mm/yr, but we could not determine this independent of the slip rate used to estimate the ages of the 6b and 6c surfaces

Figure 3 (FER-174). Table IV from Rockwell (1983) which shows estimated slip rates and related radiocarbon dates from surfaces in the Oak View area. Surface designations added.

TRENCH 4



GEOLOGIC UNITS

A A SOIL HORIZON
DARK BROWN CLAYEY SILT

B B SOIL HORIZON
DARK BROWN CLAY WITH ABUNDANT BEDROCK FRAGMENTS

wb WEATHERED BEDROCK (MONTEREY FORMATION)
LIGHT GRAY SILICEOUS SILTSTONE AND SHALE, JOINTED

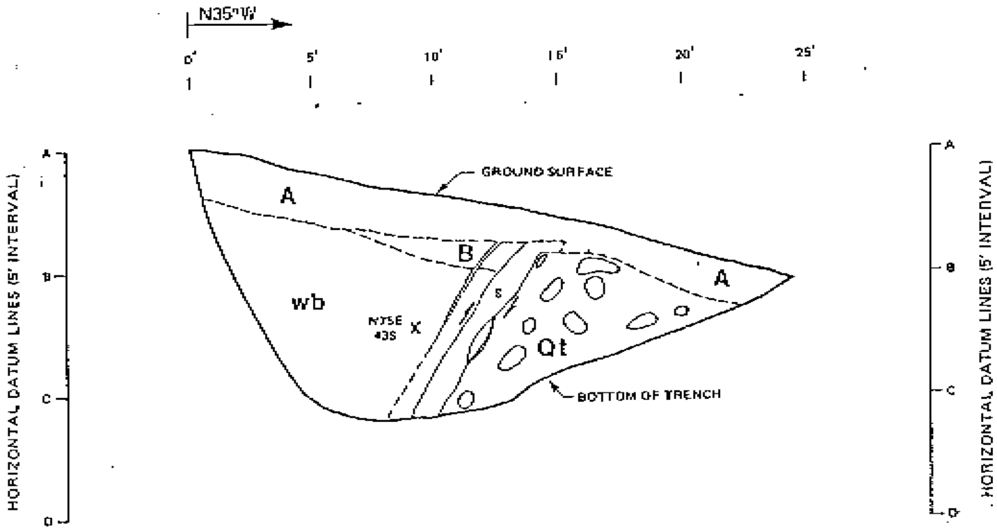
Qt QUATERNARY TERRACE
BROWN SANDY CLAY WITH ABUNDANT PEBBLE TO BOULDER SIZE SANDSTONE CLASTS

s SHEAR ZONE (FAULT BRECCIA)
GREENISH-GRAY CLAY, HIGHLY SHEARED, ABUNDANT SMALL BEDROCK FRAGMENTS

sb SHEARED BEDROCK
HIGHLY SHEARED AND PERVASIVELY FRACTURED BEDROCK, ABUNDANT CLAY

Figure 4 (FER-174). Trench log across southern Oak View fault.
From Earth Technology Corporation (ERTEC), 1981, plate 6.

TRENCH 4A



GEOLOGIC UNITS

A — A SOIL HORIZON
DARK BROWN CLAYEY SILT

B — B SOIL HORIZON
DARK BROWN CLAY WITH ABUNDANT BEDROCK FRAGMENTS

wb — WEATHERED BEDROCK (MONTEREY FROMATION)
LIGHT GRAY SILICEOUS SILTSTONE AND SHALE.
NUMEROUS DISCONTINUOUS JOINTS.

Qt — QUATERNARY TERRACE
BROWN SANDY CLAY WITH ABUNDANT PEBBLE TO BOULDER SIZE SANDSTONE CLASTS

s — SHEAR ZONE (FAULT BRECCIA)
GREENISH-GRAY CLAY, HIGHLY SHEARED, ABUNDANT SMALL BEDROCK FRAGMENTS

Figure 5 (FER-174). Trench log across southern Oak View fault.
From Earth Technology Corporation (ERTEC), 1981, plate 6.

Table V. Fault Displacement and Tilting of Alluvial Fans in Orcutt and Timber Canyons. Determinations made from USGS 7 1/2 minute topographic maps with 40 foot contour intervals and by hand level and tape measurements. Measurements are believed to be good in all cases to ± 3m for the vertical displacements and ± 0.2° for the slope determinations.

Geomorphic Surface	Displacement on Faults (Δd) Thorpe	Culbertson	Rudolph	Tilting Present Slope(s)	Degrees Tilted (Δs)	Estimated Age*(t) y.b.p.
Qf_3	4.5m	2m	6m	6°	0°	4000-5000
Qf_5	14m	4.5m	24-27m	8.2°	2.2°	25,000-30,000
Qf_6			61m	11.1°	5.1°	80,000-100,000
Qf_7	98m	37m		17°	11°	160,000-200,000

*Age estimates based on a ^{14}C date from a buried soil under Qf_3 and on correlation to well-dated soils along the Ventura River.

From Rockwell, 1983, Table V, p. 71

TABLE 1: Fault displacements and tilting of geomorphic surfaces in Orcutt and Timber Canyons.

Geomorphic Surface	Displacement on Faults(Δd) Thorpe	Culbertson	Rudolf	Tilting Present Slope(s)	Degrees Tilted(Δs)	Estimated Age(t) y.b.p.
Qf_3	4.5m	2m	6m	6.0°	0.5°	4,500-5,000
Qf_5	14m	4.5m	24-27m	8.2°	2.0°	15,000-18,000
Qf_6			61m	11.1°	4.9°	37,000-42,000
Qf_7	98m	37m		17.0°	11.5°	112,000-126,000

From Keller and others, 1981a, Table 1, p. 67

Figure 6 (FER-174). Tables showing amount of offset and tilting associated with geomorphic surfaces near Orcutt and Timber canyons. Note discrepancy is estimated ages of surfaces.

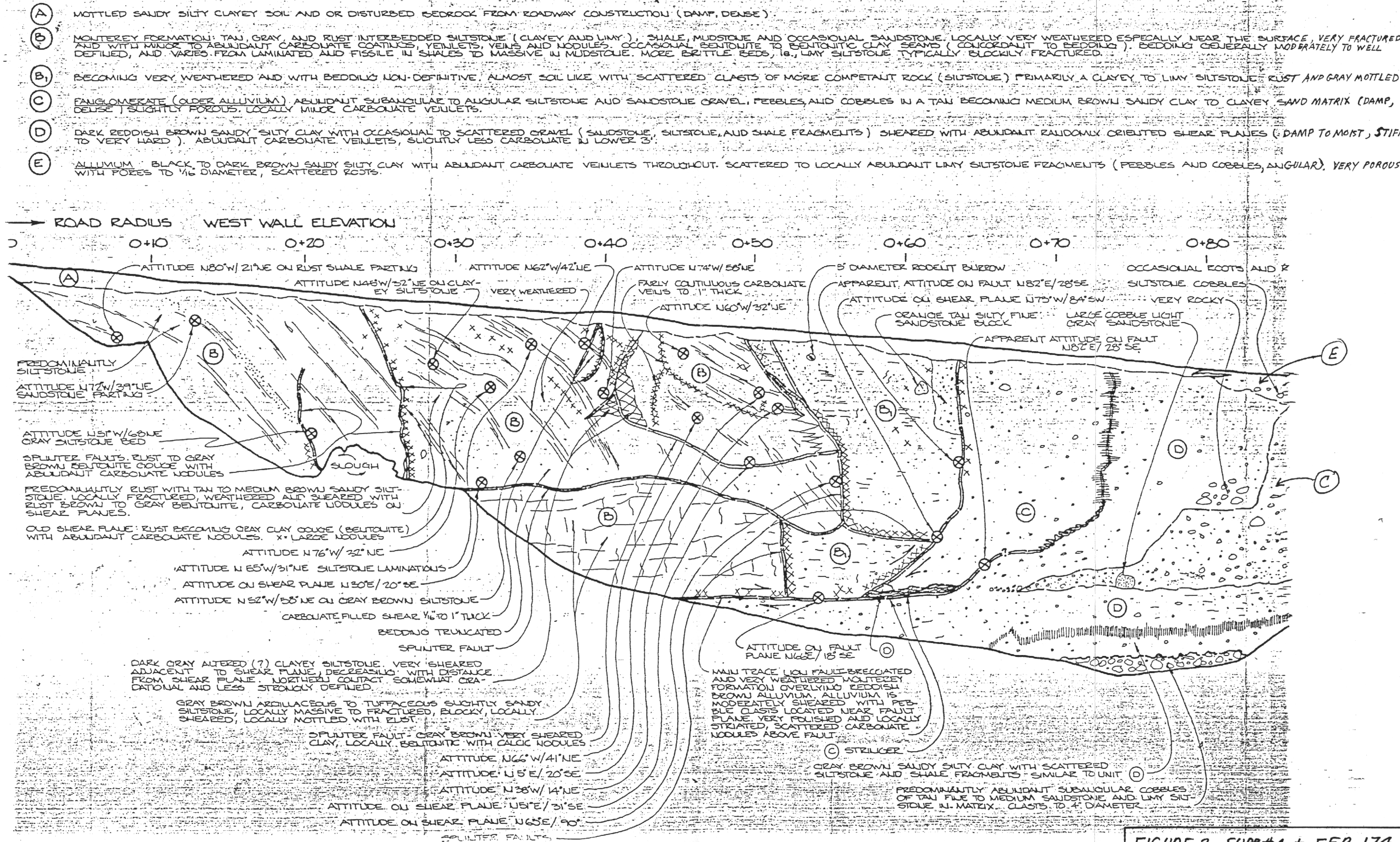


FIGURE 3, SUPP #1 to FER-174
Part of trench log showing alleged Lion fault. From Gorian and Associates (1983) Geotechical Cross Section No. 2.

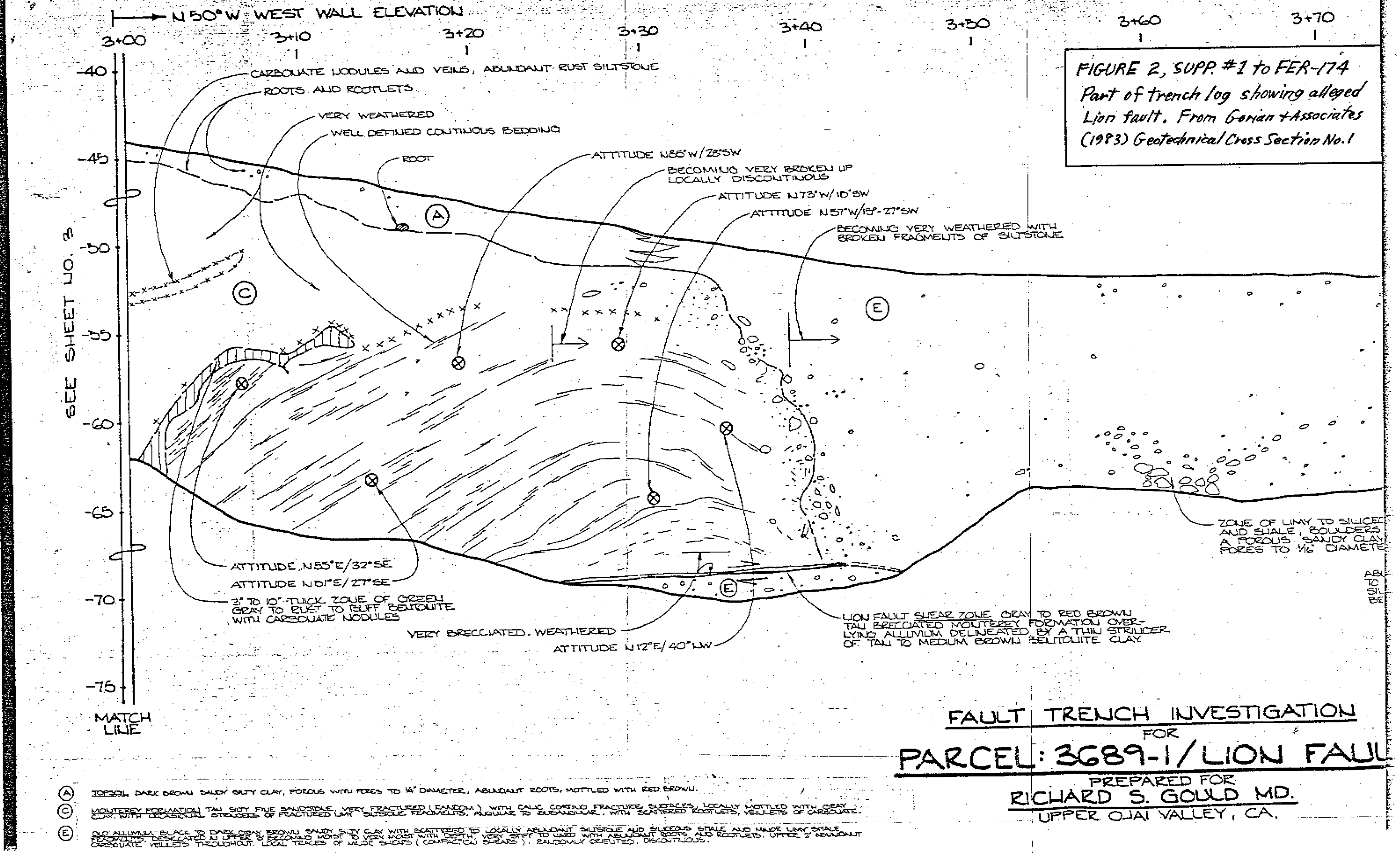


FIGURE 2, SUPP. #1 to FER-174
Part of trench log showing alleged Lion fault. From Gorian + Associates (1983) Geotechnical Cross Section No. 1